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TUNED MUFFLER FOR SMALL INTERNAL COMBUSTION ENGINES

Cross Reference to Related Applications

This application claims the benefit under Title 35, U.S.C. § 119(e) of U.S. Provisional Patent Application Serial No. 60/463,820, entitled TUNED MUFFLER FOR SMALL INTERNAL COMBUSTION ENGINES, filed on April 18, 2003.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

[0001] The present invention relates to mufflers for use with small internal combustion engines, such as engines of the type which are used with lawnmowers, lawn tractors, other working implements, or in sport vehicles.

2. Description of the Related Art.

[0002] Typically, mufflers used with small internal combustion engines are attached directly to the exhaust port of the engine cylinder, or alternatively, may be mounted remotely from the engine and attached to the exhaust port of the engine cylinder by one or more exhaust pipes which communicate exhaust gases from the cylinder to the muffler. The construction of such mufflers varies greatly. However, such mufflers often include a muffler shell having a muffler tube or one of more baffles disposed therein, the muffler tube and/or baffles having a plurality of holes for silencing the noise associated with the exhaust gases. The exhaust gases typically exit the muffler either through an open end of the muffler tube or through holes or slots in the muffler shell. Known mufflers for small internal combustion engines have been designed almost solely for the purpose of reducing the noises associated with the exhaust gases and making the mufflers inexpensive and easy to manufacture.

[0003] Some mufflers for larger engines of the type used in performance vehicles have included exhaust tuning features to enhance engine performance in addition to reducing exhaust noise. For example, one method of exhaust tuning, used with two-cycle engines, involves the use of a straight, elongated exhaust pipe which includes an area of gradually expanding or diverging cross section, allowing the exhaust gases to expand when passing therethrough. In this manner, as the exhaust gases encounter the area of expanding cross

section of the exhaust pipe, the expanding of the pressure waves associated with the exhaust gases reflect negative pressure waves back toward the exhaust port. These reflected, negative pressure waves aid in scavenging exhaust gases from the combustion chamber of the cylinder through the exhaust port, which in turn allows a greater amount of air/fuel combustion mixture to enter the combustion chamber to enhance engine performance.

[0004] Problematically, such tuned exhaust systems often require lengthy straight exhaust piping, which is not practical for use in the mufflers of small internal combustion engines because such engines are designed to be compact in size.

[0005] What is needed is a compact muffler for use in small internal combustion engines, particularly 4-cycle engines, the muffler including exhaust tuning features to enhance engine performance while also providing exhaust noise reduction.

SUMMARY OF THE INVENTION

[0006] The present invention provides a tuned muffler for small, single cylinder internal combustion engines, particularly 4-cycle engines. The muffler includes a first shell having an exhaust inlet, a central plate, and a second shell having an exhaust outlet. The central plate is disposed between the first and second shells, and the foregoing components define an exhaust path therethrough which includes a first expansion volume, a first passage, a second expansion volume, and a second passage. The first and second expansion volumes and the first and second passages are dimensioned to provide an exhaust tuning effect to enhance engine performance, and also to provide an exhaust flow path which conducts the exhaust gas smoothly through the muffler to substantially reduce back pressure within the muffler. Additionally, the shapes of the first and second expansion volumes and the first and second passages are configured to provide a compact overall profile to the muffler, such that the muffler may be conveniently used with small internal combustion engines.

[0007] More specifically, in a preferred form of the invention, the first shell is secured directly to the exhaust port of the engine, and includes a plurality of walls which, together with the central plate, define the second passage. The second shell includes a plurality of walls which, together with the central plate, define the first passage. The first and second expansion volumes are defined by the first and second shells and by the central plate. In operation, exhaust gas from the engine enters the first shell and the first expansion volume before passing through the first passage. In the first passage, the exhaust gas turns through an

angle of approximately 270° before entering the second expansion volume. After exiting the second expansion volume, the exhaust gas passes through the second passage, turning therein through an angle of approximately 270° before entering a tail pipe and exiting through the exhaust outlet. The first and second passages each have a substantially constant cross-sectional area along the lengths thereof.

[0008] The dimensions of the first expansion volume, first passage, second expansion volume, and second passage are collectively configured to provide a tuning effect to the exhaust gases, wherein when the exhaust gases exit the muffler, expansion of the exhaust gases into the atmosphere generates reflective pressure waves which are reflected back through the muffler to the exhaust port. The reflective waves each reach the engine's combustion chamber during the valve overlap period of the engine cycle when the intake and exhaust valves are both open, to aid in scavenging spent combustion products from the combustion chamber and to increase the efficiency of the entry of air/fuel combustion mixture into the combustion chamber, providing enhanced engine power output and performance.

[0009] Additionally, in one form of the invention, a pair of resonance chambers, sometimes referred to as "pinch cans" are defined between the tail pipe and the first and second shells. A portion of the exhaust gases pass through perforations in the tail pipe and into each of the resonance chambers, in which the high frequency waves in the exhaust gases are trapped. The waves resonate within in the resonance chambers and loose their energy, thereby reducing high frequency noises associated with the exhaust gases.

[0010] The dimensions and shapes of the first and second muffler shells, and the walls therein, preferably are configured to provide a smooth exhaust flow path having smooth flow transitions between the first and second expansion volumes and the first and second passages, thereby reducing back pressure in the muffler by avoiding abrupt changes in flow direction of the exhaust gases to enhance the performance of the muffler.

[0011] In one form thereof, the present invention provides a muffler for a small internal combustion engine, including a housing having an inlet and an outlet; an exhaust flow path defined within the housing, the exhaust flow path including first and second passages and at least one expansion volume, the exhaust flow path dimensioned to provide an exhaust tuning effect to exhaust gasses which pass through the muffler.

[0012] In another form thereof, the present invention provides a muffler for a small internal combustion engine, including a housing having an inlet and an outlet; an exhaust flow path defined within the housing, the exhaust flow path dimensioned to provide an exhaust tuning effect to exhaust gasses passing through the muffler, the exhaust flow path including first and second passages, each of the first and second passages being curved through an angle of at least 180°; and at least one expansion volume.

[0013] In a further form thereof, the present invention provides the combination of a small, single cylinder internal combustion engine having an exhaust port; and a muffler attached to the engine, the muffler including an exhaust flow path defined within the muffler, including an inlet in fluid communication with the exhaust port and an outlet in fluid communication with the atmosphere, the exhaust flow path dimensioned to provide a tuning effect to exhaust gases produced by the engine.

[0014] In a still further form thereof, the present invention provides a muffler for use with a small internal combustion engine, the muffler including a first shell including an exhaust inlet and containing a first portion of an exhaust passage, the first portion of the exhaust passage curved through an angle of at least 180°; a second shell including an exhaust outlet and containing a second portion of the exhaust passage, the second portion of the exhaust passage curved through an angle of at least 180°; and a partition element disposed between the first and second shells, the partition element substantially separating the first and second portions of the exhaust passages.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

[0016] Fig. 1 is perspective view of a small, single cylinder internal combustion engine having a muffler in accordance with the present invention;

[0017] Fig. 2 is a cutaway perspective view of the engine and muffler of Fig. 1, showing the internal components of the engine, as well as the manner in which the muffler may be attached to the exhaust port of the engine;

[0018] Fig. 3 is a first exploded view of the muffler, showing the first muffler shell, the central plate, and the second muffler shell;

[0019] Fig. 4 is a second exploded view of the muffler, showing the first muffler shell, the central plate, and the second muffler shell;

[0020] Fig. 5 is a first perspective view of the muffler, schematically showing the exhaust gas flow therethrough;

[0021] Fig. 6 is a second perspective view of the muffler, schematically showing the exhaust gas flow path therethrough; and

[0022] Fig. 7 is a is a plot of engine speed vs. engine horsepower for an engine having a conventional muffler and for an engine having a muffler in accordance with the present invention.

[0023] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplification set out herein illustrates one preferred embodiment of the invention, in one form, and such exemplification is not to be construed as limiting the scope of the invention any manner.

DETAILED DESCRIPTION

[0024] Referring to Figs. 1 and 2, a small internal combustion engine 20 is shown, which generally includes crankcase 22 supporting a vertically-oriented crankshaft 24 for rotation therein. Engine 20 may be any single cylinder, vertical or horizontal crankshaft engine such as those manufactured by Tecumseh Products Company, for example. Cylinder 26 is attached to crankcase 22, and includes cylinder bore 28 having piston 30 reciprocatingly disposed therein. Piston 30 is attached to crankshaft 24 by a connecting rod (not shown) in a conventional manner. Exhaust port 32 is in communication with combustion chamber 34 of cylinder 26, and is periodically opened and closed by exhaust valve 36 according to a conventional four-stroke timing cycle during running of engine 20. Exhaust valve 36, and an intake valve (not shown) disposed directly beneath exhaust valve 36, are each disposed radially adjacent cylinder bore 28, and are actuated by a cam arrangement (not shown) driven from crankshaft 24. Thus, engine 20 has a side valve or "L-head" valve train, however, the valve train of engine 20 may vary.

[0025] Referring to Figs. 3 and 4, muffler 50 in accordance with the present invention will now be described. Muffler 50 generally includes first shell 52, second shell 54, and central

plate 56, which each may be made of a suitable metal such as sheet metal or stainless steel, for example. First shell 52 and second shell 54 each include apertures 58 through which fasteners 60 are inserted, as shown in Fig. 2, which fasteners 60 also engage apertures 40 in connecting flange 38 of exhaust port 32 to connect muffler 50 to exhaust port 32.

[0026] Also, as shown in Figs. 3 and 4, first shell 52, second shell 54, and central plate 56 each include a plurality of apertures 62 around the external peripheries thereof through which fasteners 64, such as rivets, are inserted to fasten first shell 52 to second shell 54 with central plate 56 captured between first shell 52 and second shell 54. Alternatively, one of first and second shells 52 and 54 may have a peripheral edge thereof crimped over central plate 56 and over the peripheral edge of the other of first and second shells 52 and 54 to attach the foregoing components together.

[0027] First shell 52 generally includes main body 66, having base wall 68 with side wall 70 depending therefrom, and extension portion 72 extending from main body 66. As may be seen from Figs. 3 and 4, side wall 70 has a curved profile, and extension potion 72 has a box-like profile. Extension portion 72 includes exhaust inlet 74 and apertures 58. Referring to Fig. 4, main body 66 of first shell 52 also includes first, second, and third interior walls 76, 78, and 80, respectively.

[0028] Second shell 54 includes main body 82, having base wall 84 with side wall 86 depending therefrom, and extension portion 88 extending from main body 66. As may be seen from Figs. 3 and 4, side wall 86 has a curved profile, and extension potion 88 has a box-like profile. Exhaust outlet 90 is defined centrally within base wall 84, and extension portion 88 includes apertures 58 which, when first and second shells 52, 54 are attached to one another, are aligned with apertures 58 in extension portion 72 of first shell 52. Referring to Fig. 3, main body 82 of second shell 54 includes fourth interior wall 92 which has an oval shape.

[0029] Central plate 56 includes first opening 94, second opening 96, and third opening 98. Tail pipe 100 is mounted within third opening 98, and includes inlet end 102 (Fig. 3), outlet end 104 (Fig. 4), and two sets of holes 106a and 106b disposed between inlet end 102 and outlet end 104.

[0030] When first shell 52 and second shell 54 are assembled to one another with central plate 56 therebetween, a first expansion volume 108 is defined between extension portion 72 of first shell 52, first interior wall 76, first opening 94 of central plate 56, and extension

portion 88 of second shell 54. First expansion volume 108 is adjacent exhaust inlet 74, and may have a volume of between about 5.0 and 7.5 cubic inches (in^3), preferably about 6.8 in^3.

[0031] First exhaust passage 110 is defined generally within main body 82 of second shell 54, as well as by central plate 56 and fourth interior wall 92 of second shell 54. First passage includes inlet end 112 in fluid communication with first expansion volume 108, and outlet end 114 in fluid communication with second expansion volume 118. First passage 110 is curved or bent around fourth interior wall 92 within second shell 54 through an angle of approximately 270°, including three approximately 90° turns 116a, 116b, and 116c. First passage 110 may have a length of about 8.0 inches. Also, the internal diameter of first passage 110 may be between about 0.985 and about 1.04 inches, preferably about 1.0 inch.

[0032] Second expansion volume 118 is defined between first shell 52, second opening 96 in central plate 56, and second shell 54, and is in fluid communication with outlet end 114 of first passage 110. Second expansion volume 118 has a volume of between about 1.5 and about 4.0 in^3, preferably about 2.9 in^3. Second expansion volume 118 may be considered a transition volume between first passage 110 and second passage 120.

[0033] Second passage 120 is defined generally within main body 66 of first shell 52, by base wall 68 and first and second interior walls 76 and 78 thereof, as well as by central plate 56. Second passage 120 includes inlet end 122 in fluid communication with second expansion volume 118, and outlet end 124 in fluid communication with tail pipe 100. Second passage 120 is bent or curved around third interior wall 80 within first shell 52 and into tail pipe 100 through an angle of approximately 270°, including three approximately 90° turns 126a, 126b, and 126c. Second passage 120 has a length of about 9.5 inches. The internal diameter of second passage 120 may be between about 0.985 and about 1.04 inches, preferably about 1.0 inches.

[0034] Although exemplary lengths for first and second passages 110 and 120 are set forth above, the length of same may be varied. However, the total length of first and second passages 110 and 120 are typically between about 17.0 and about 18.0 inches. Exemplary internal diameters for first and second passages 110 and 120 are also set forth above. Generally, within the given ranges set forth above, a larger internal diameter for first and second passages 110 and 120 will be accompanied by a smaller volume for first expansion volume 108, and a smaller internal diameter for first and second passages 110 and 120 will be accompanied by a larger volume for first expansion volume 108.

[0035] Additionally, tail pipe 100 may be considered part of second passage 120, with tail pipe 100 having a length of about 1.1 inches and an inner diameter of about 1.33 inches. First and second exhaust passages 110 and 120 each have a substantially constant cross-sectional area along the lengths thereof, with the cross sectional area of each of first and second passages 110 and 120 varying less than about 10%, preferably less than about 5%, along the lengths of first and second exhaust passages 110 and 120.

[0036] Referring to Figs. 5 and 6, a first resonance volume 128 is defined between inlet end 102 of tail pipe 100, third interior wall 80 of first shell 52, base wall 68 of first shell 52, fourth interior wall 92 of second shell 54, and base wall 84 of second shell 54. First resonance volume 128 is in fluid communication with tail pipe 100 through holes 106a in tail pipe 100. Second expansion volume 130 is defined between inlet end 102 of tail pipe 100, central plate 56, fourth interior wall 92 of second shell 54, and base wall 84 of second shell 54, and is in fluid communication with tail pipe 100 through holes 106b in tail pipe 100. First and second expansion volumes 128 and 130 each have a "half moon" shape or profile. First and second expansion volumes 128 and 130 are also known as "pinch can" volumes, and are Helmholtz-type resonators, the operation of which is discussed below.

[0037] In operation, the flow of exhaust gases through muffler 50 is shown by arrows in Figs. 3-6. Exhaust gases from exhaust port 32 of engine 20 enter inlet 74 of first shell 52 into first expansion volume 108, and then pass successively through first passage 110, second expansion volume 118, second passage 120, and tail pipe 100 before exiting muffler 50 through outlet 90 in second shell 54.

[0038] As may be seen from Figs. 3-6, the exhaust gases first travel through first passage 110 defined within second shell 54, which may be considered an outer layer of muffler 50 which is spaced distally from engine 20, before passing through second passage 120 within first shell 52, which may be considered an inner layer of muffler 50 which is spaced proximally to engine 20. Thus, the transfer of heat from the exhaust gases to the atmosphere is facilitated, as the exhaust gases are hottest when same initially enter muffler 50 and pass through first passage 110 distally from engine 20. Also, as described below, the foregoing exhaust path is dimensioned to provide an exhaust tuning effect to increase the performance of engine 20.

[0039] Specifically, exhaust gas propagates through the foregoing exhaust path in successive pressure waves, each pressure wave corresponding to an opening of exhaust valve 36 to vent

combustion products from combustion chamber 34 through exhaust port 32. As each pressure wave exits through outlet 90 into the atmosphere, the abrupt change in the volume occupied by the pressure wave generates a reflective pressure wave which propagates back through the exhaust path in the opposite direction. The various section of the exhaust path in muffler 50 are dimensioned as discussed above, such that each reflective pressure wave reaches the exhaust valve 36 during the valve overlap period of the timing cycle of engine 20, in which both exhaust valve 36 and the intake valve are open. In most small four cycle engines, the valve overlap period is around the top dead center ("TDC") position of the piston, when the piston is completing its exhaust stroke and beginning its intake stroke. The reflective pressure waves aid in scavenging the combustion products from combustion chamber 34, and thereby also promote the entry of fuel/air combustion mixture into combustion chamber 34 during each cycle of engine 20.

[0040] As shown in Fig. 7, the exhaust tuning effect increases the output power of an engine 20 to which muffler 50 is attached. Fig. 7 is a plot of engine speed vs. engine horsepower for engine 20 having a conventional muffler and for engine 20 having muffler 50 in accordance with the present invention. Engine 20 is a small, 4-cycle internal combustion engine. Specifically, curve 132 in Fig. 7 shows the power output of engine 20 over varying speeds with a conventional muffler, and curve 134 in Fig. 7 shows the power output of engine 20 over varying speeds with muffler 50 of the present invention. As may be seen from Fig. 7 and from the corresponding data in Table I below, muffler 50 provides a substantially increased power output for engine 20 over a broad range of engine speeds

TABLE I

Engine Speed (RPM)	Engine Horsepower (Hp) with a conventional muffler	Engine Horsepower (Hp) with muffler 50 of Figs. 1-6
2400	2.86	2.95
2600	3.08	3.21
2800	3.28	3.41
3000	3.41	3.67
3200	3.53	3.77
3400	3.61	3.88
3600	3.61	3.98
3800	3.59	4.02
4000	3.49	3.94

[0041] Also, in tail pipe 100, a first portion of the exhaust gases enter first resonance volume 128 through holes 106a in tail pipe 100, and a second portion of the exhaust gases enter second resonance volume 130 through holes 106b in tail pipe 100. High frequency waves associated with the exhaust gases are trapped and resonate within first and second resonance volumes 128 and 130, losing their energy to thereby attenuate or reduce high frequency noises associated with the exhaust gases.

[0042] Additionally, as shown in Fig. 2, base walls 68 and 84 of first and second shells 52 and 54, respectively, may optionally include ridges 136. Ridges 136 may be integrally formed in base walls 68 and 84 by stamping, for example. Alternatively, ridges 136 may be in the form of separate pieces which are secured to base walls 68 and 84 by welding, for example. Ridges 136 stiffen and rigidify first and second shells 52 and 54 such that, when exhaust gases contact first and second shells 52 and 54, vibration of first and second shells 52 and 54 is reduced to attenuate exhaust gas noise.

[0043] As may be seen from Figs. 3-6, the exhaust flow path through muffler 50, including for example, the transition between first expansion volume 108 and first passage 110, the path of first passage 110, the transition between first passage 110 through second expansion volume 118 and into second passage 120, and the path of second passage 120 to outlet 90, is arranged such that exhaust gases are smoothly carried therethrough with an avoidance of any abrupt turning of the exhaust gases. In this manner, the exhaust gas flow path through each of the foregoing portions of muffler 50 is smooth and uninterrupted to substantially reduce or avoid back pressure within muffler 50.

[0044] While this invention has been described as having a preferred design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.